Project EarthShade

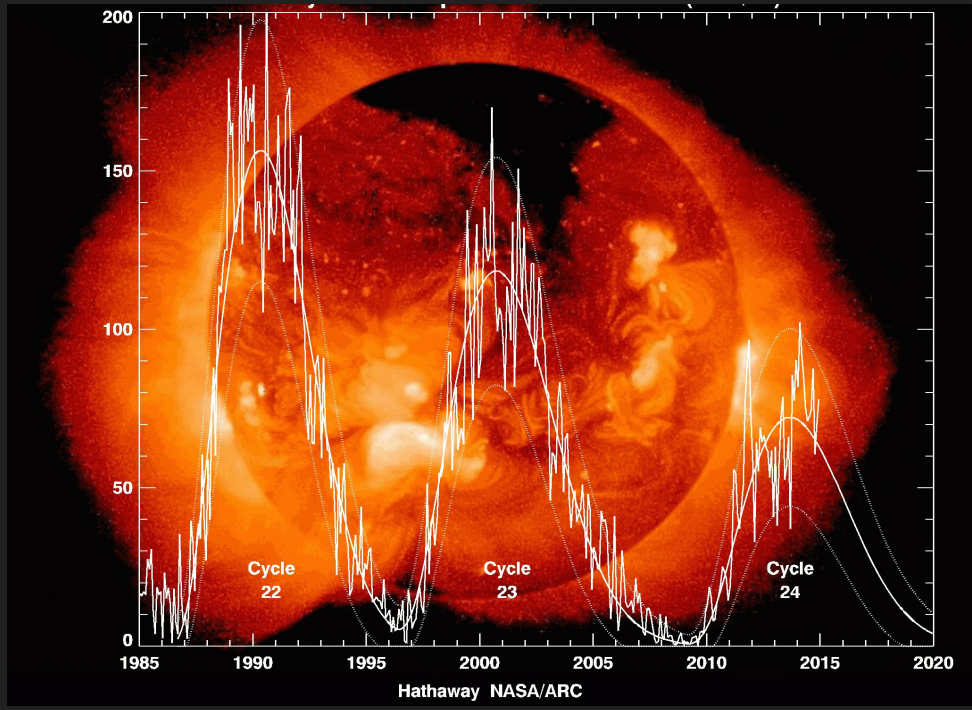
Global climate management with space-based sunshades

Luke M.
Hart T.
Damian C.

New worlds 2022 V2.2

Climate Change Mechanisms

Solar output variability
Other celestial bodies
Atmospheric chemistry changes
Volcanism
Life
Anthropogenic



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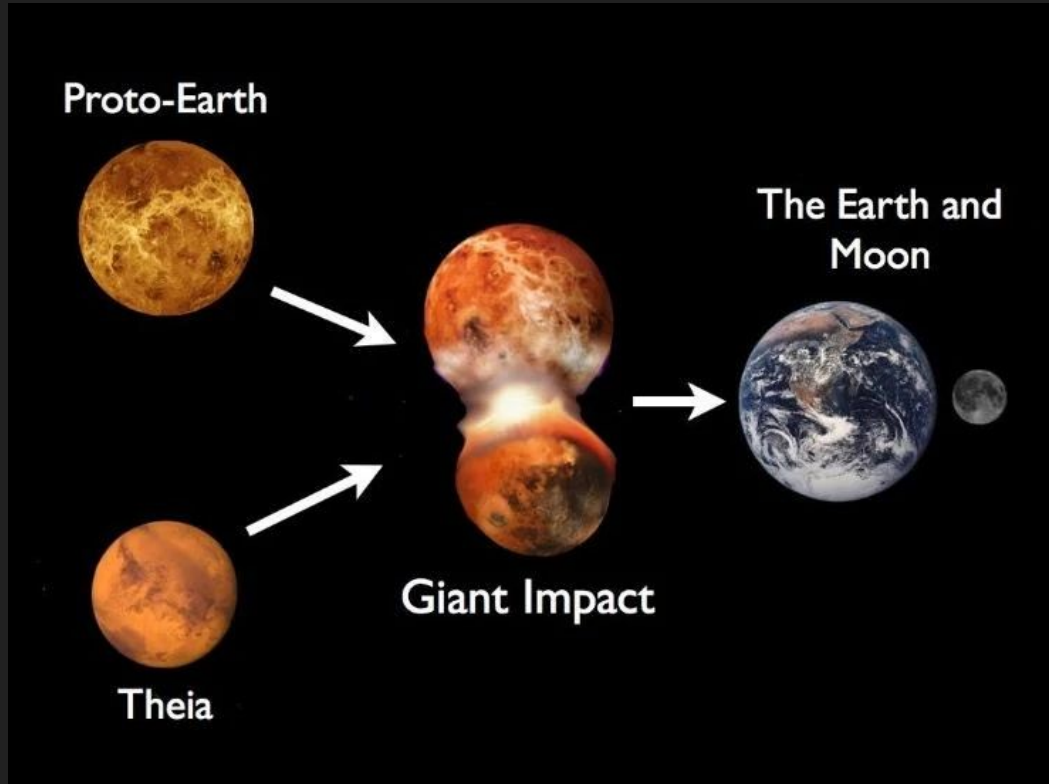

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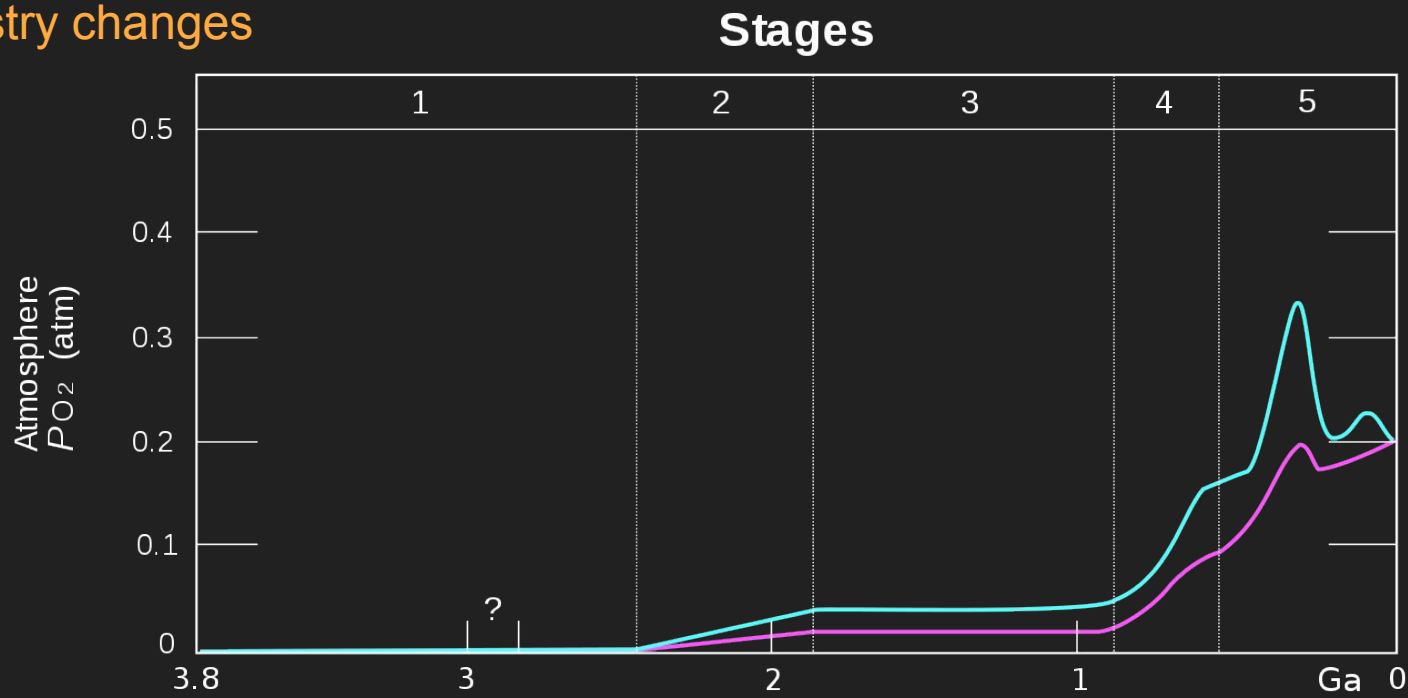

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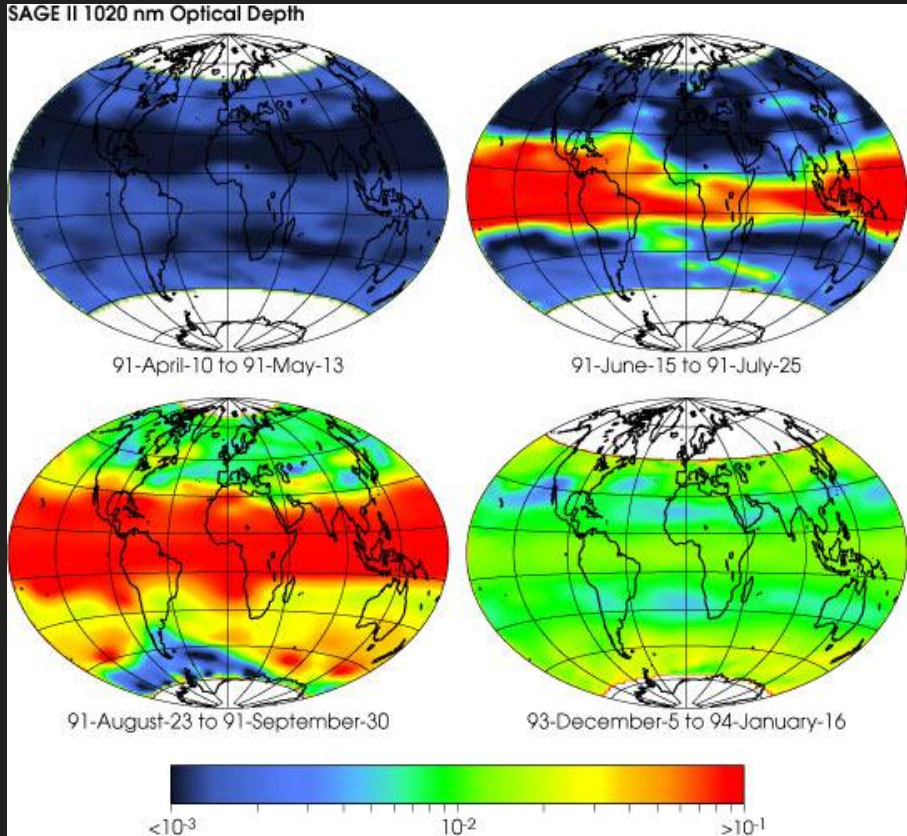

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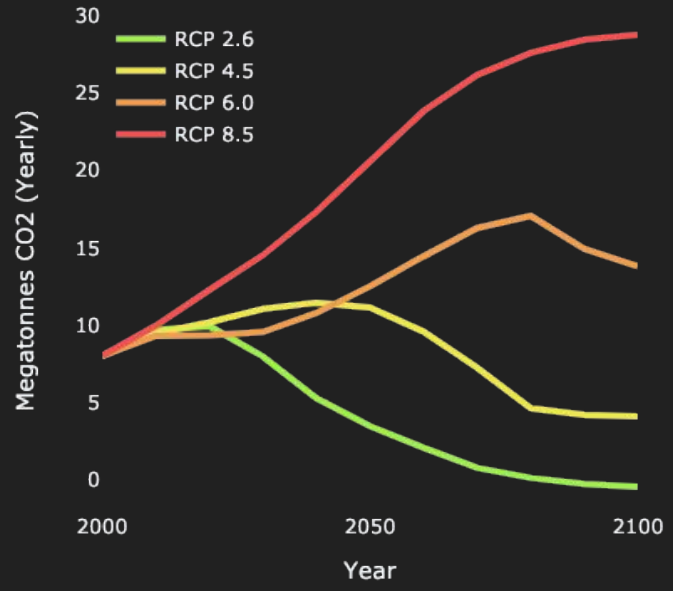
Climate Change Solutions

Emissions reduction
Ocean fertilization
Stratospheric aerosols injection
Ice cap augmentation
Subglacial dewatering
Space-based sunshades

Figure 1: Yearly CO2 Emissions



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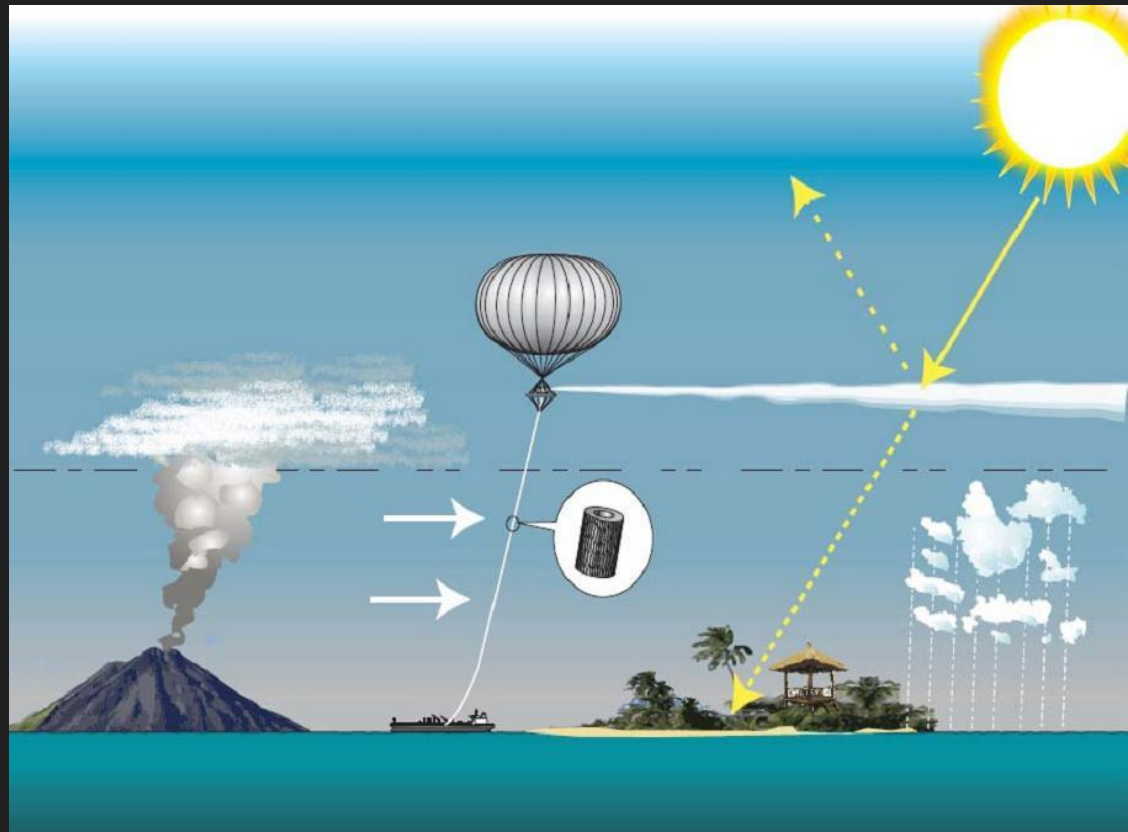

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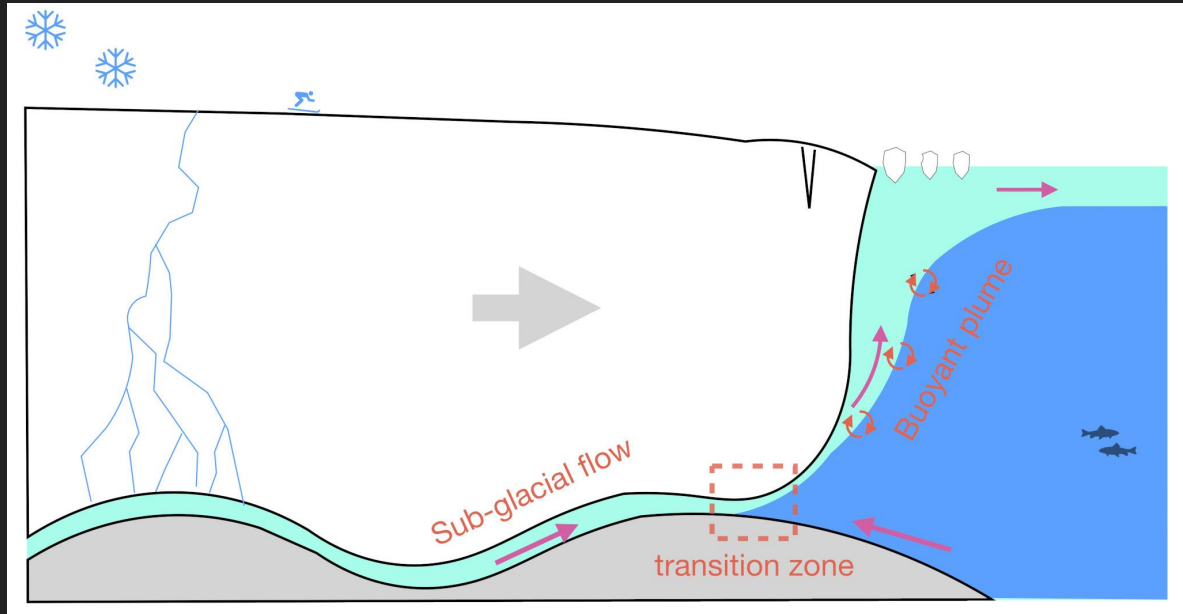

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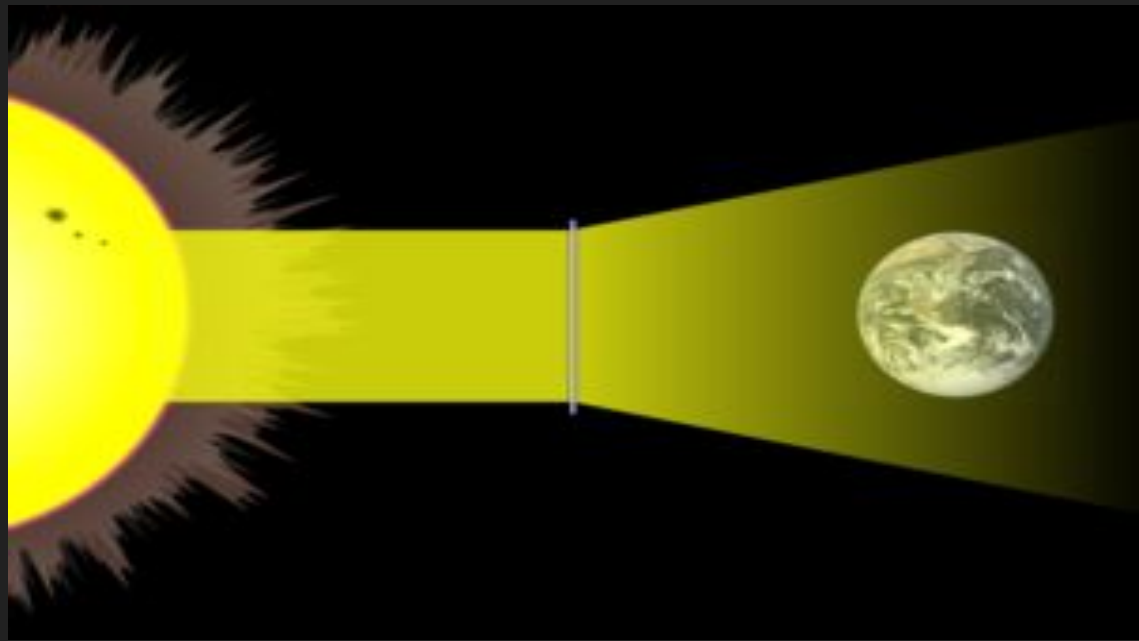
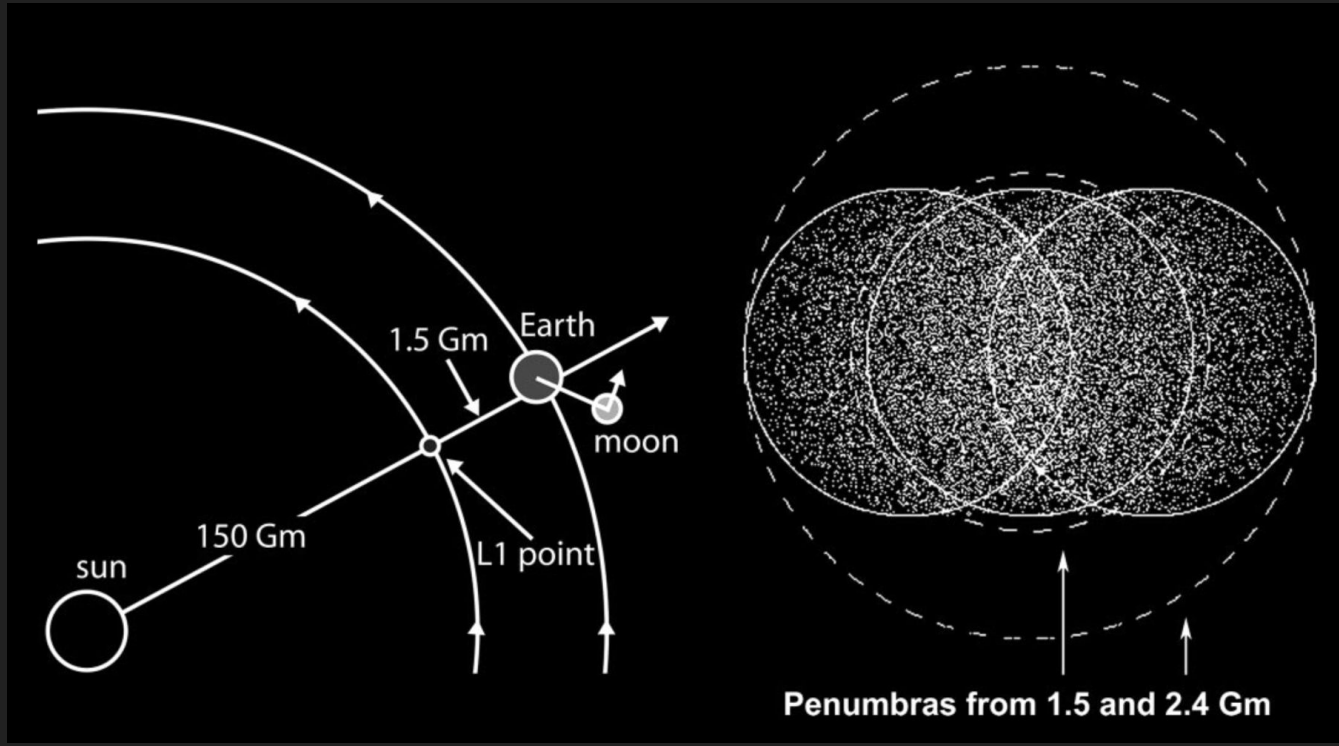


Sunshade Basics



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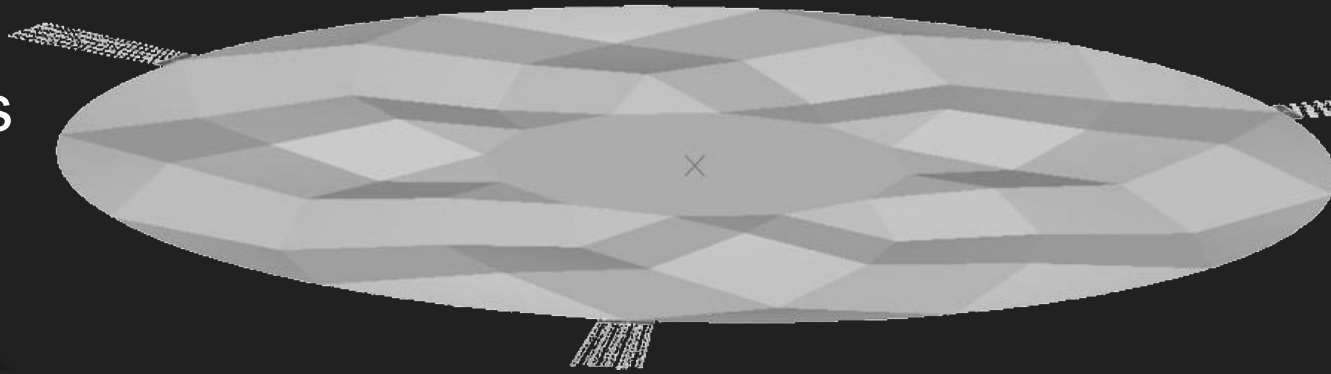
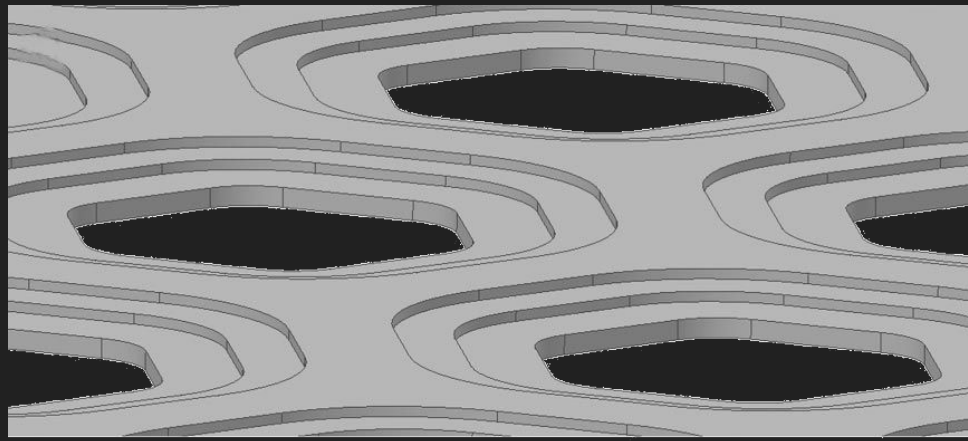


Micro-textured diffractive glass
Solar “wings” with MEMS activation



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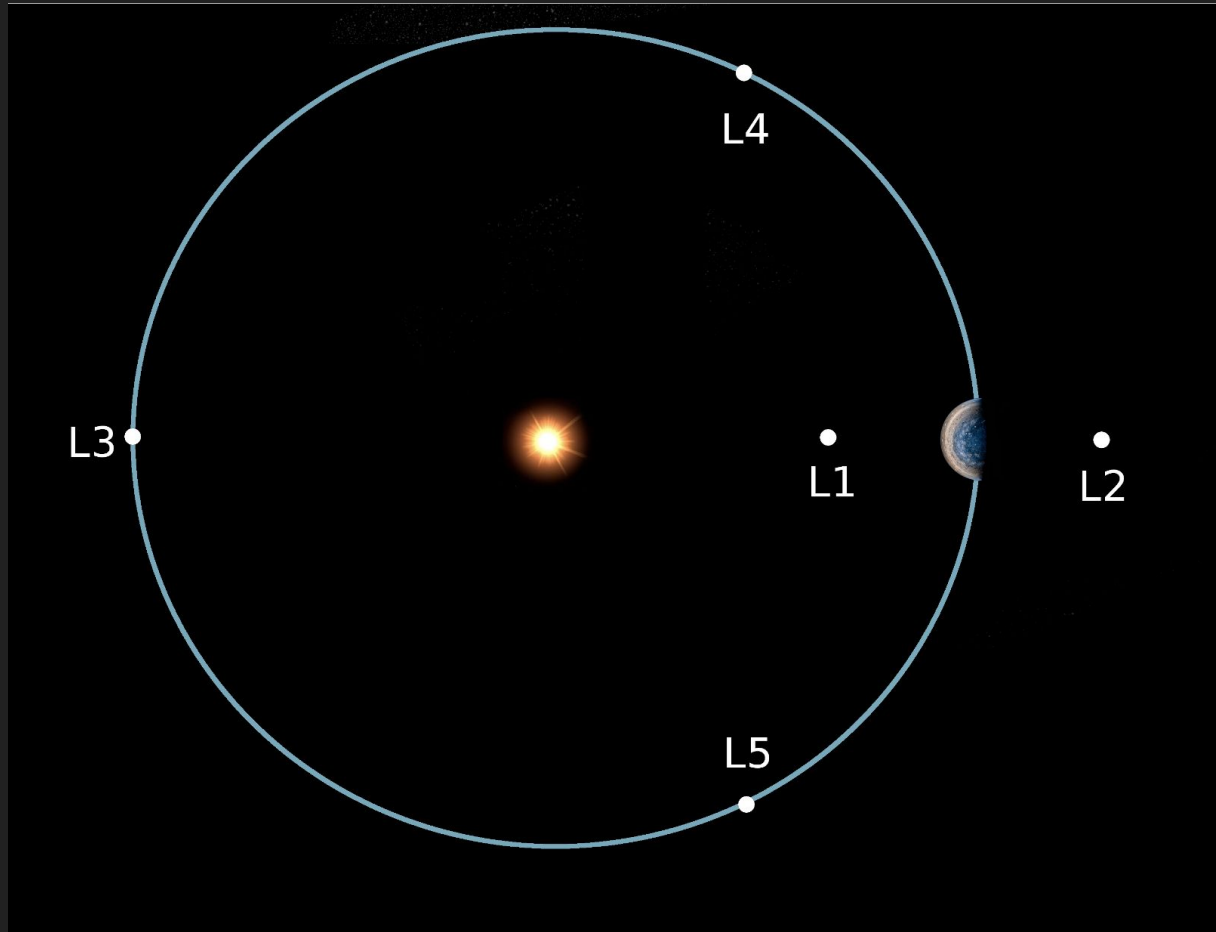

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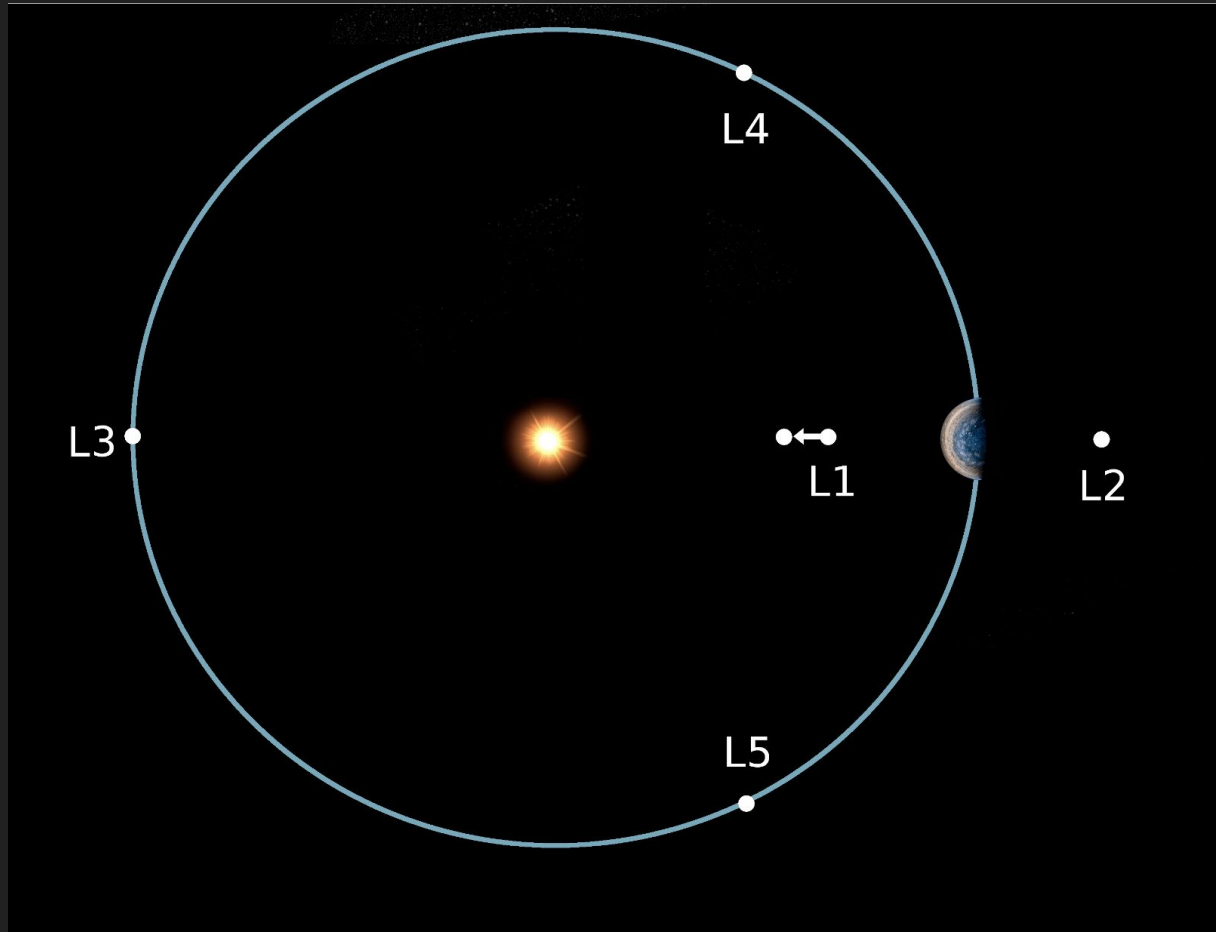
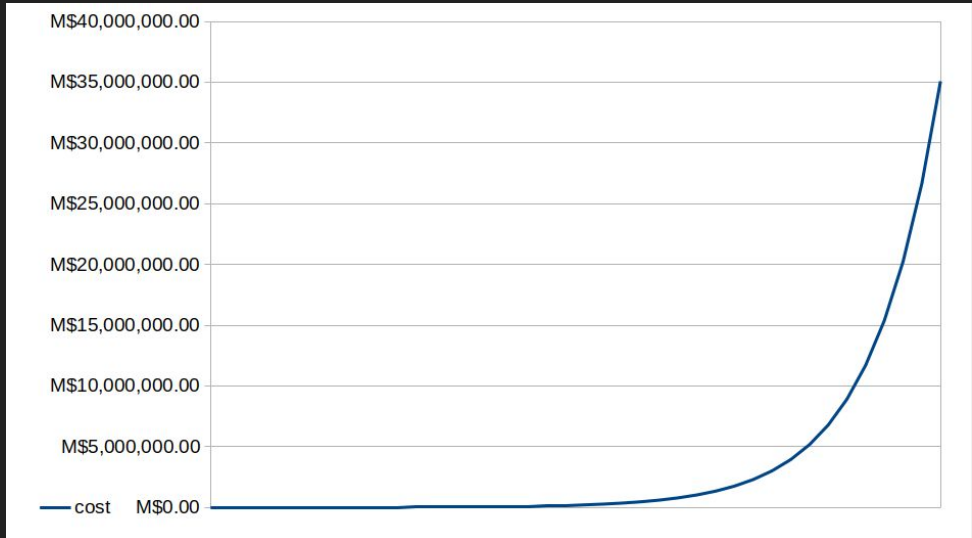


Sunshade Dimensions

0.5-2% of sunlight blocked
6,000,000 km^2
20 - 25 MT

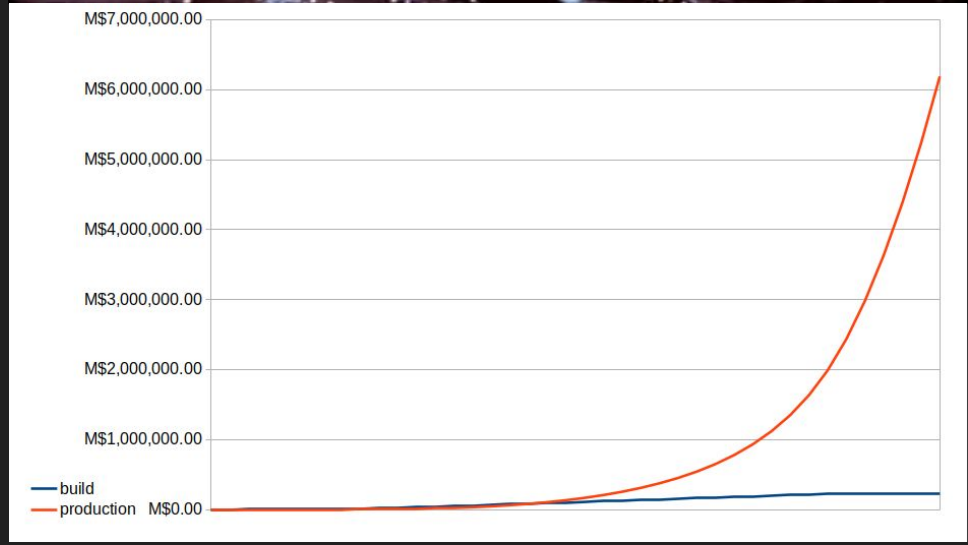
Source of Materials: Earth

Many rocket launches (330k-1M)
Environmental imapact: CO_2, heat, waste
Extremely expensive (~$35T)



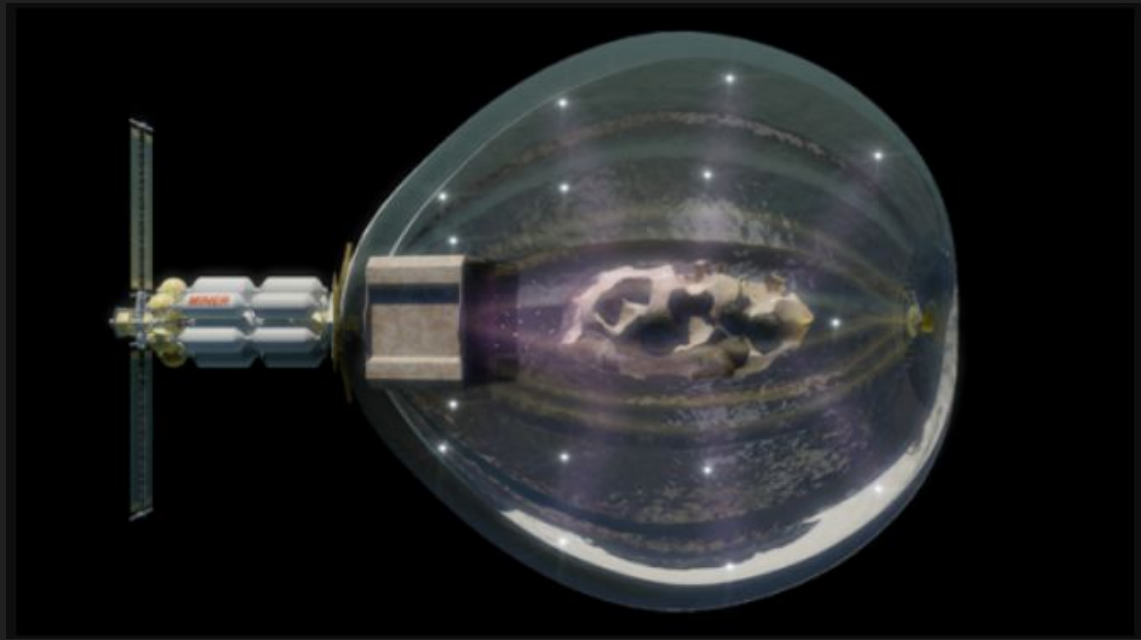
Source of Materials: Moon

Fewer Earth launches
Cheaper: lower Delta-V
Complicated
Very expensive:
- $100B infrastructure
- $6T total



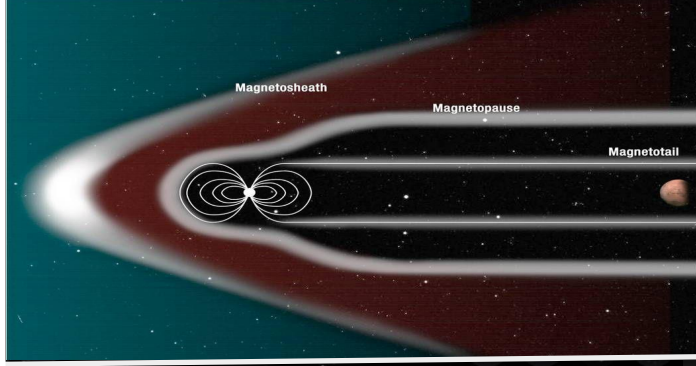
Source of Materials: Asteroids

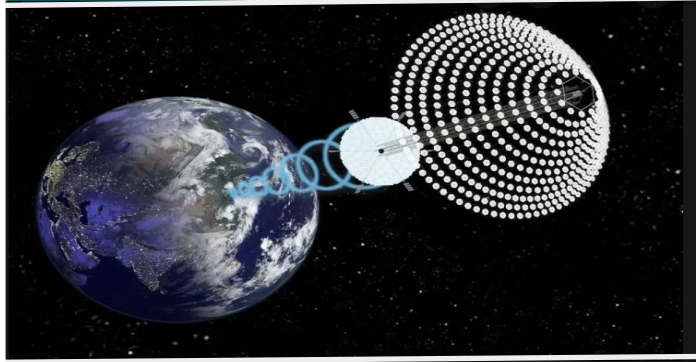
Even lower Delta-V
Factory near L1 for additional shade
Beyond scope of this presentation
Heterogeneous approach

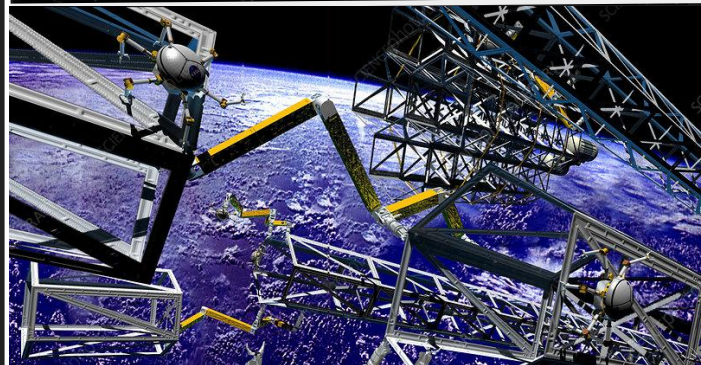


Other Infrastructure Applications

Solar Flare Protection
Space Based Solar Power
Bulk construction materials
Launch Assist Structures
Orbital Shipyards
Space Habitats







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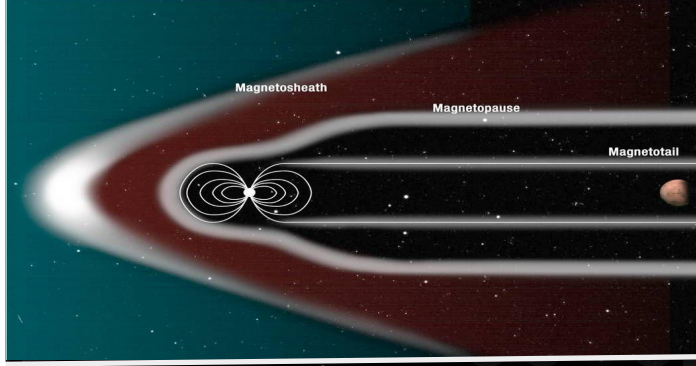

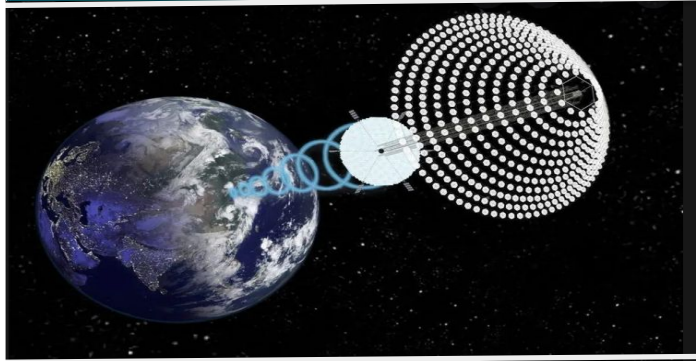

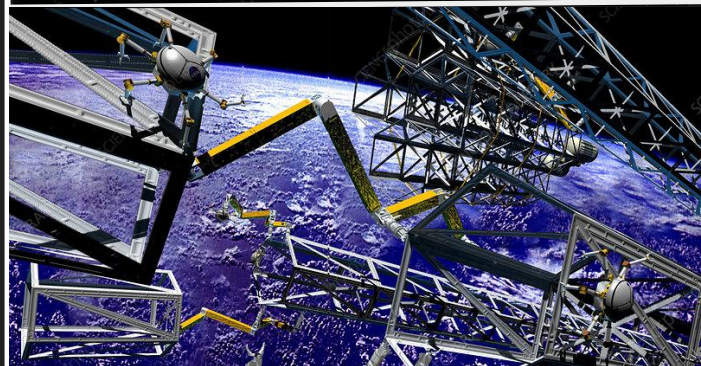

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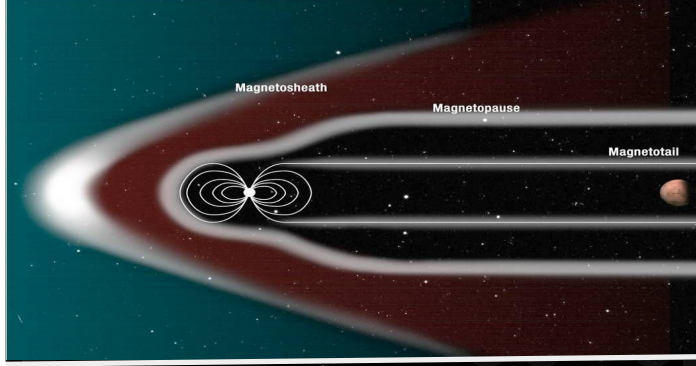

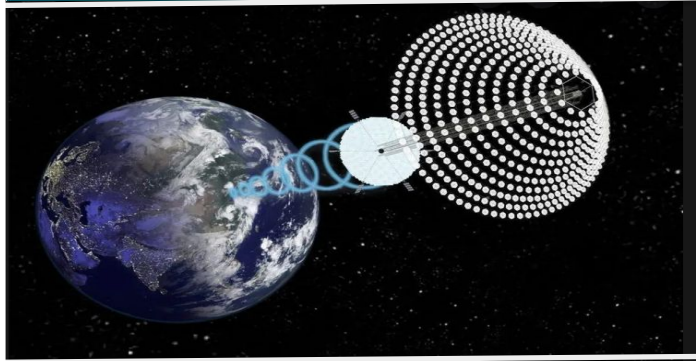

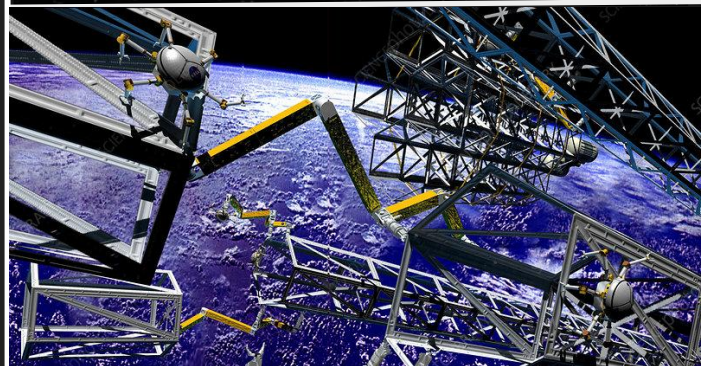

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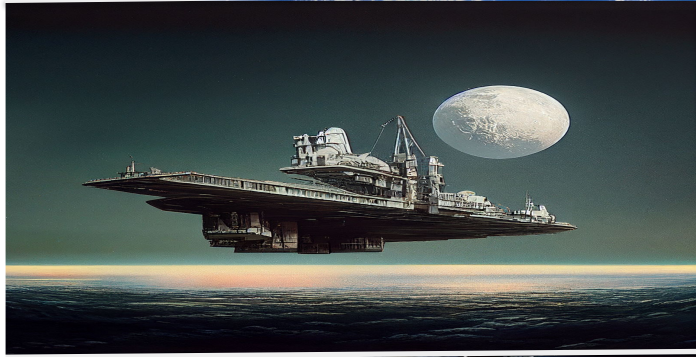

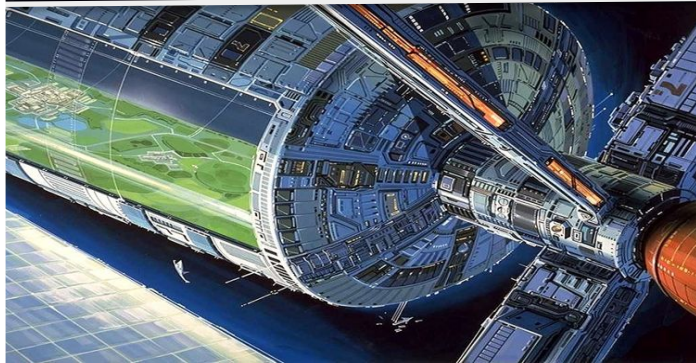

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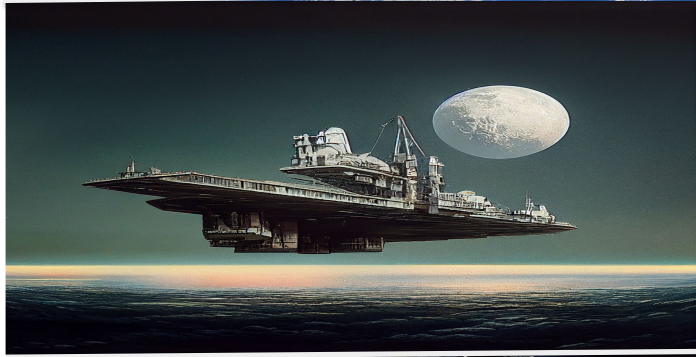

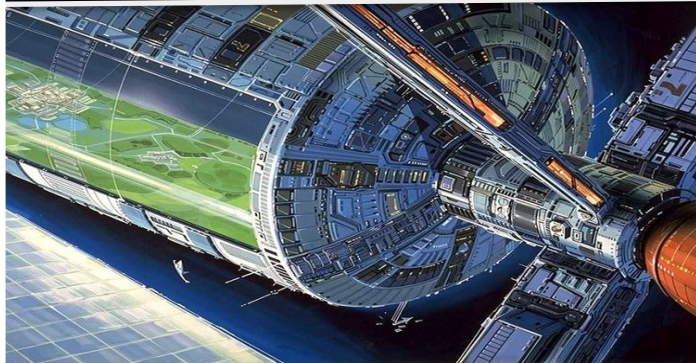

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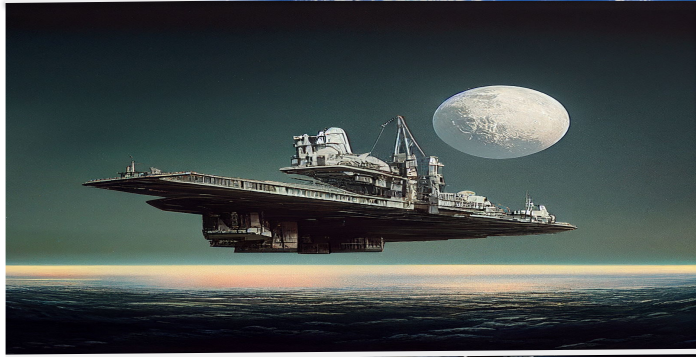
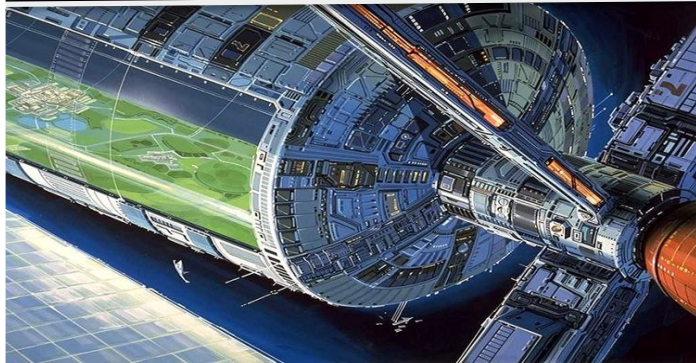


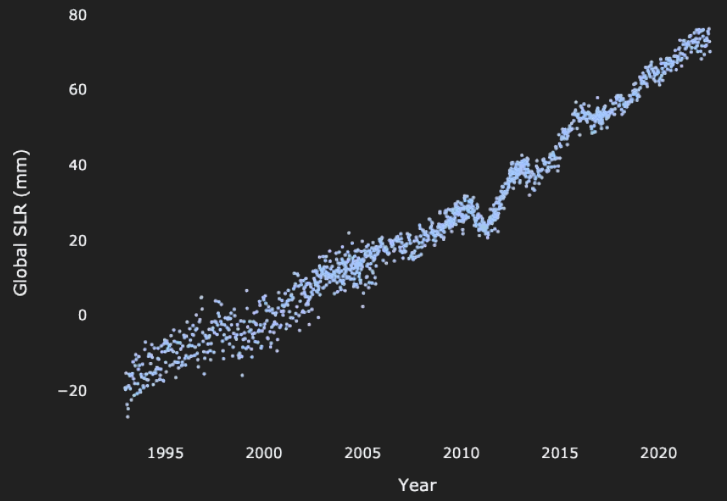


Cost of Inaction: Through the lens of Miami

Hart Traveller

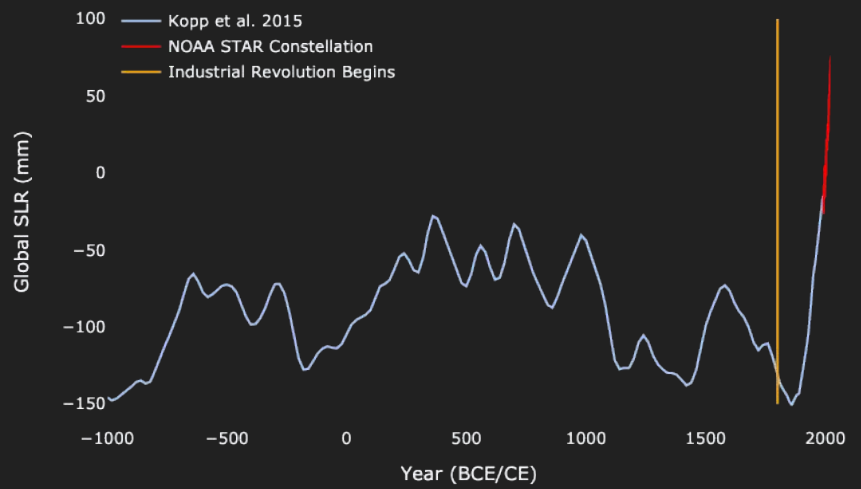
A View of Historical Sea Level Rise (SLR)

Short Term: (Illusory) Linear Trend



Visualization created with data from:
data source: *NOAA STAR Satellite Constellation*
data download: *slr_sla_gbl_free_txj1j2_90.csv*

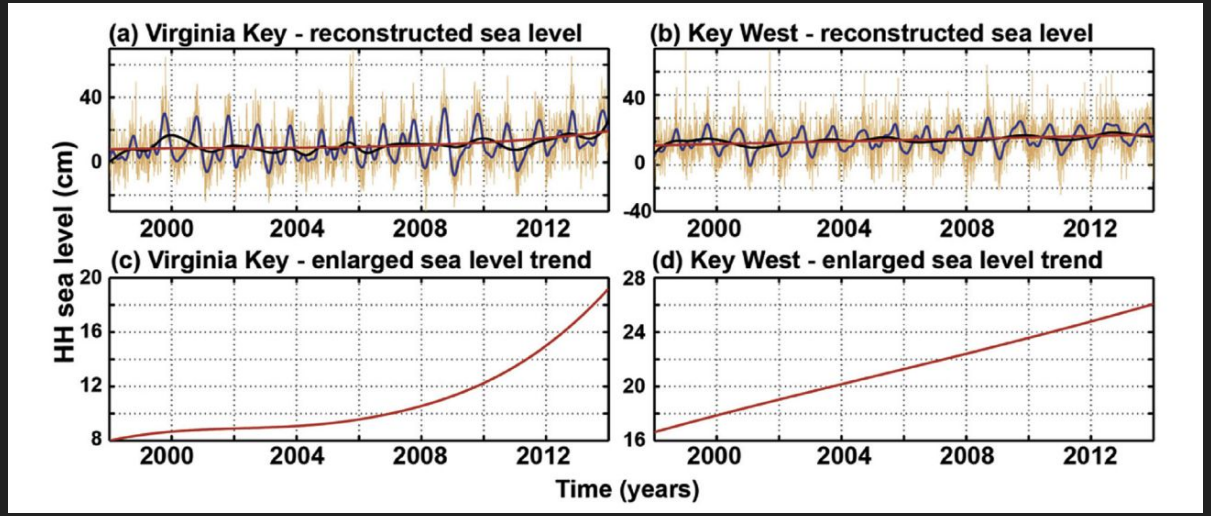
Long Term: Clear Non-Linearity



Visualization created with data from:
data source: *Temperature-driven global… Kopp et al.*
data download: *pnas.1517056113.sd03.xls*

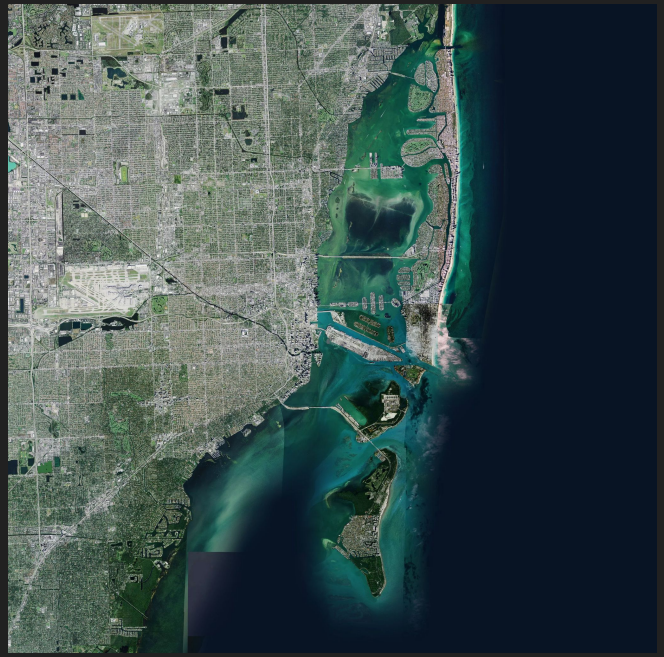
Local SLR vs. Global SLR

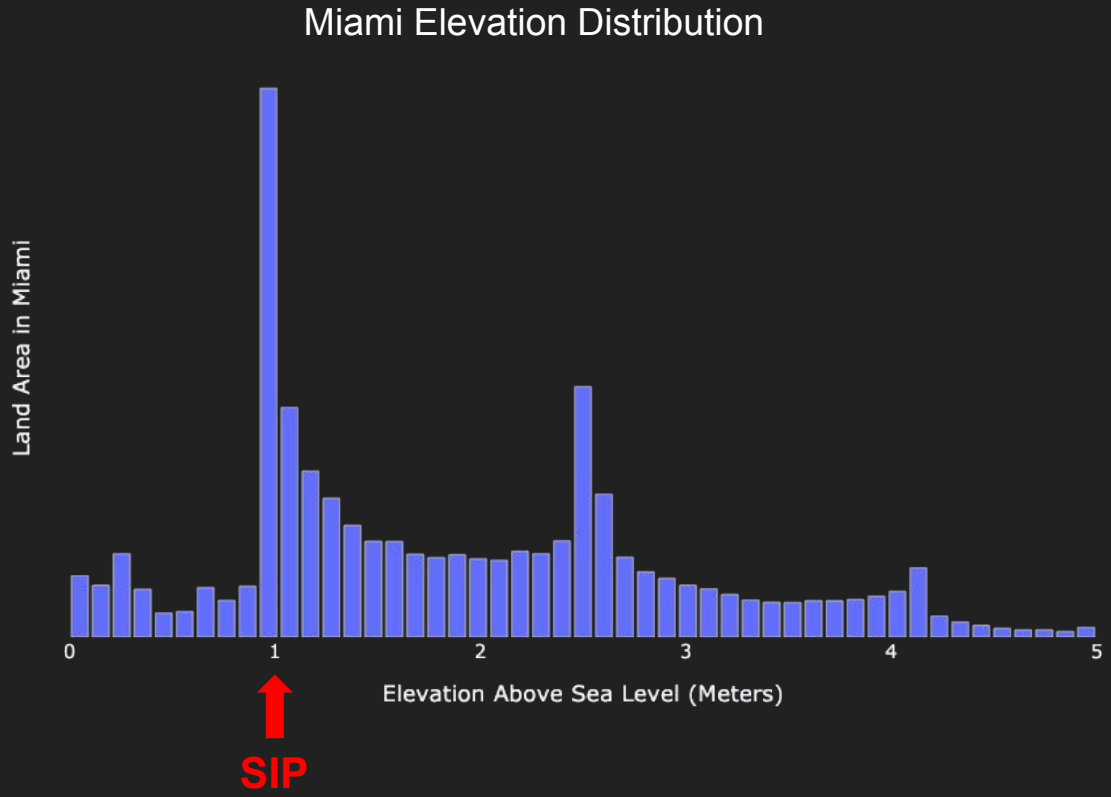
The average pre-2006 rate is 3 ± 2 mm/yr, similar to the global long-term rate of SLR, whereas after 2006 the average rate of SLR in Southeast Florida rose to 9 ± 4 mm/yr. Our results suggest that engineering solutions to SLR should rely on regional SLR rate projections and not only on the commonly used global SLR projections. **The accelerated rate of SLR in Southeast Florida and other locations along the US Atlantic coast are significantly higher than the global average rate of SLR.**



Source:
Increasing flooding hazard in coastal communities. Wdowinski et al.

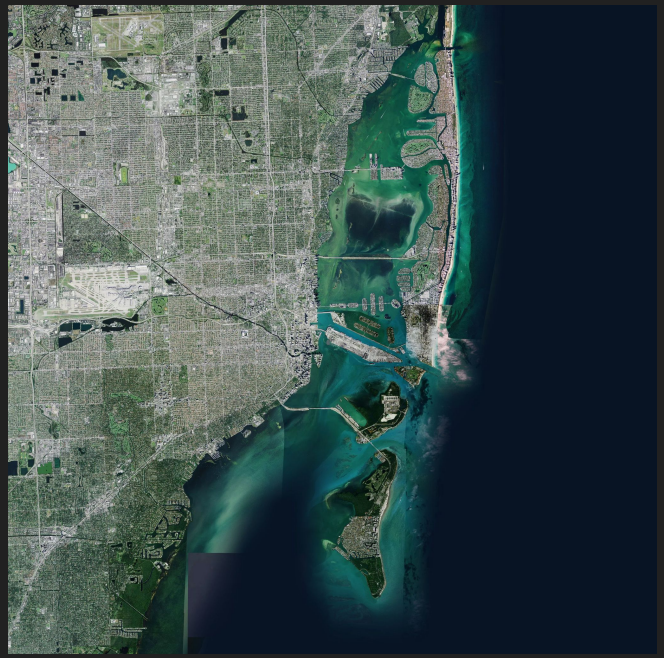
Miami: Abrupt **S**LR **I**nflection **P**oint (SIP)





What would the SIP look like?

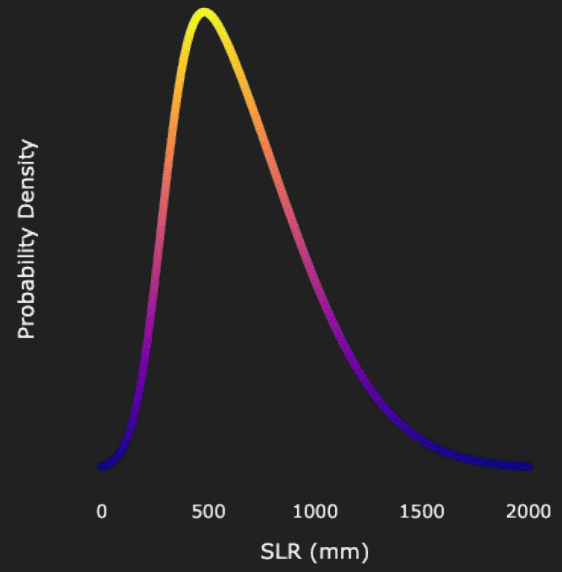
Pre-SIP Miami



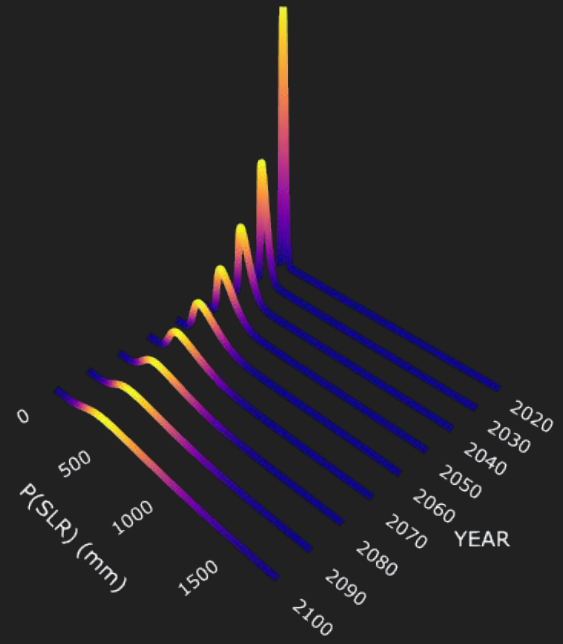
Post-SIP Miami

Global SLR Probability Distributions

2100 Global SLR Probability Dist.



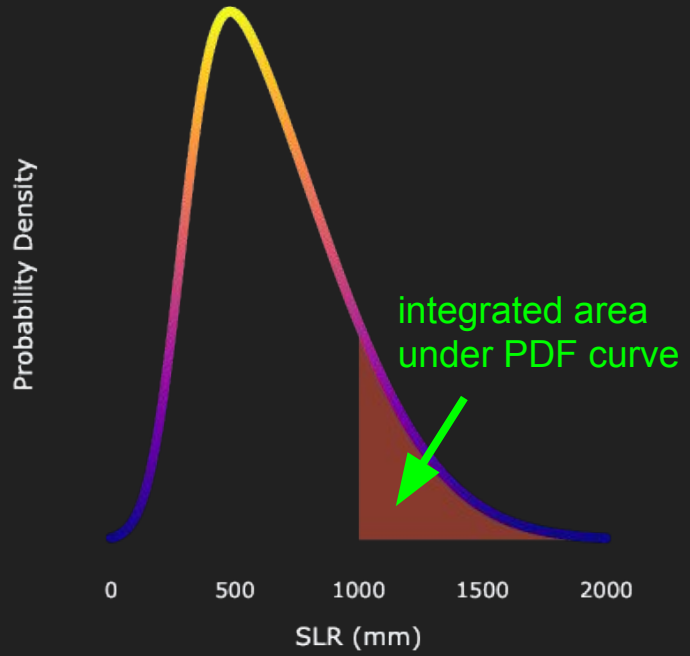
Global SLR Probability Dist. by Year



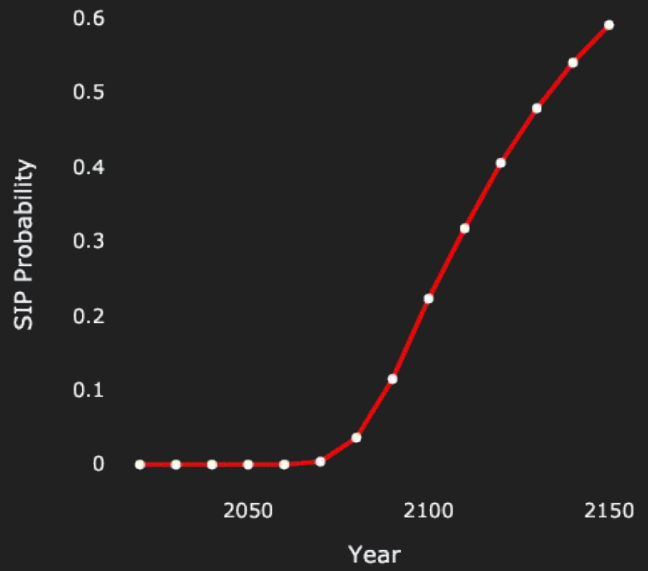
Visualization and models created with data from: *IPCC AR6 Relative Sea Level Projection Distributions*

Temporal Probability Estimation of the SIP

2100 Global SLR Probability Dist.



P(SIP) vs. Year, Assuming Global SLR Rate



Visualization and models created with data from: *IPCC AR6 Relative Sea Level Projection Distributions*

An Important Point on SIP Estimation

Source:
Max Olson Chasing

An Important Point on SIP Estimation

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Max Olson Chasing

Pre-SIP Costs

Source:
[Curtis + Rogers Design Studio]

US Army Corps of Engineers Estimate: ~$3.1B over 50 years

Protects critical infrastructure:

- fire stations
- medical facilities
- police stations
- potable water facilities
- wastewater facilities
- EOC facilities
- airport facilities

This alternative makes use of Floodproofing, Elevation and acquisition to protect these structures.

Human Life Costs: Extreme Weather Events

Given FEMA estimate of $7.5M per person, recent hurricane had an impact of $855,000,000.

Note: Of course - the motivation for action should be not the economic productivity of a life. The fact it is a human life alone ought to be sufficient.

Post-SIP Costs

USACE Critical Infrastructure Estimates

$103,000,000,000

source: MIAMI-DADE BACK BAY COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

Contrasting with 2018 CA Wildfires

$148,000,000,000

source: Economic footprint of California wildfires in 2018

Occupancy Type	Description	Count	Most Likely DRV of Structures
COM1	Average Retail	2,517	$2.12 Billion
COM10	Garage	123	$61 Million
COM2	Average Wholesale	3,642	$6.79 Billion
COM3	Average Personal & Repair Services	1,670	$614 Million
COM4	Average Professional / Tech Services	1,535	$1.09 Billion
COM5	Bank	145	$144 Million
COM6	Hospital	27	$164 Million
COM7	Average Medical Office	34	$48 Million
COM8	Average Entertainment / Recreation	988	$408 Million
COM9	Average Theatre	12	$25 Million
EDU1	Average School	415	$365 Million
EDU2	Average College / University	38	$20 Million
GOV1	Average Government Services	2,575	$1.83 Billion
GOV2	Average Emergency Response	702	$1.27 Billion
HRISE	High-rise Structure, 4 stories and above	2682	$44.69 Billion
IND1	Average Heavy Industrial	210	$670 Million
IND2	Average Light Industrial	358	$695 Million
IND3	Average Food / Drug / Chem	1,602	$3.49 Billion
IND4	Average Metals / Minerals processing	56	$32 Million
IND6	Average Construction	1,519	$325 Million
REL1	Church	1,043	$673 Million
RES1-1SNB	Res 1, 1 Story no Basement	123,092	$17.26 Billion
RES1-2SNB	Res 1, 2 Story no Basement	7,450	$2.40 Billion
RES1-3SNB	Res 1, 3 Story no Basement	1,555	$619 Million
RES2	Mobile Home	3,481	$139 Million
RES3A	Condominium, 1 Story	28,303	$8.03 Billion
RES3B	Condominium, 2-3 Stories	10,055	$8.47 Billion
RES4	Average Hotel, & Motel	397	$356 Million
RES5	Nursing Home	1	$2.6 Million
RES6	Nursing Home	216	$192 Million
Grand Total		**196,443**	**$103 Billion**

Cost of Inaction: Key Takeaways

Miami Estimated Cost by 2100

- Infrastructure costs (to prevent damage)
- Repair costs (for damage incurred by extreme weather)
- Human life loss costs (due to extreme weather events)
- SIP estimated cost (*P(SIP) * costs*)
  - Infrastructure loss
  - Economic output cost (re: wildfires)

So what is the estimated cost by 2100 on Miami?

If we zoom out to the big picture, the entire United States of America -

What can we do?

- Pathfinder mission
- Raise awareness

- Agitate to NASA etc.

- Film/television

Conclusion

Questions?

Sources

1) Trajectory Design for Asteroid Retrieval
   https://www.frontiersin.org/articles/10.3389/fams.2018.00044/full
2) Sunshade Mass
   https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1859907/
3) Intercepting Apophis
   https://space.nss.org/technologies-for-asteroid-capture-into-earth-orbit/
4) Solar Flare Shade
   https://www.newsweek.com/doomsday-solar-flare-carrington-event-2022-earth-today-1720964
5) ELEO Habitats
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Image References

1) Sunshade Concept
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3) SpaceX Starship Earth Launch
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4) Lunar Mass Driver
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